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ICT

FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY ICT

APPLIED ELECTROCHEMISTRY

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Batteries, fuel cells, electrochemical sensors and analysis systems are the research focus of the Applied Electrochemistry Department at the Fraunhofer Institute for Chemical Technology ICT. A wide range of civil and military research and development activities are carried out, from the evaluation and optimization of materials through to method development and the production of prototypes. Extensive testing and development methods for fuel cells, batteries and battery components have been developed and form part of our service.

BATTERIES

Research and development in the competence area of batteries includes material and system development as well as testing and in-situ and post-mortem analyses of electrochemical energy storage devices for stationary and mobile applications. For the future stationary storage of renewable energies, redox-flow batteries are an efficent and promising candidate. Other research areas include lithium-ion technology (in particular safety issues) and the development of new electrochemical storage devices, such as lithium-sulfur accumulators or sodium-based systems.

Material and system development

Advances in mobile entertainment and communication devices and their new features, as well as hybrid and electric vehicles, are closely linked to energy supply. Fraunhofer ICT has more than 30 years of experience in the development of accumulators, and is working on materials for safe and efficient lithium-ion batteries.

Development work at Fraunhofer ICT focuses on:

- Electrochemical characterization of lithium-ion cell components in specific test cells
- Measurement of the released energy and heat flows in the thermal runaway of the cell
- Application-specific performance tests from the cell up to the battery pack with capacities of several kWh
- Determination of specific, thermal parameters of lithium-ion cells
- Thermal simulation calculations for sizing the cooling structures in lithium-ion modules and battery packs
- In-situ electrolysis tests during cycling to determine aging and electrolyte decomposition
- Investigations of next generation systems
- Development of sulfur and Li_2S cathodes with a high content and fraction of active materials
  - Investigation of lithium and sodium metal anodes with aligned electrolytes
  - Testing and synthesis of sodium intercalation electrodes
  - Set-up of demonstrators up to 1 Ah

Safety tests

Electrochemical energy storage devices, including lithium-ion systems, are potentially hazardous when operated outside their specifications, due to their high energy density and the materials used. A precondition for the safe use of lithium-ion cells is compliance with temperature and potential limits. By expanding our battery laboratories, we are able to carry out comprehensive electrical, thermal and mechanical safety tests. The measurement of relevant electrical parameters for modules and battery packs, even under different climatic conditions, is the basis of the analysis. It is useful for assessing the performance of electrochemical energy storage devices and estimating the risks of operating them. We also perform destructive and non-destructive investigations on cell and module level. An almost unique accompanying online analysis of the decomposition products allows qualification and quantification of the substances released in the event of a failure. This can be used to evaluate the safety, to gradually improve it, and to conduct a risk assessment for the application.

COVER PHOTO:
Test stand for in-operando measurement of catalyst corrosion at PEMFC.

PHOTO LEFT:
Protective gas box for material development.

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Fraunhofer ICT offers the following services:

- Electrical, thermal and mechanical abuse tests on lithium-ion systems (currently) up to 2 kWh storage size
- Customized design of test environments and test scenarios
- Compatibility checks for novel battery components
- Qualitative and quantitative gas analysis by thermal, mechanical or electrical abuse tests

In addition, we have extensive experience in the aging and failure mechanisms of electrochemical storage devices. On this basis, post-mortem analyses of new, aged, improperly functioning or destroyed cells or batteries are carried out. The causes of the failure can be determined and possible changes can be made.

Since a new test building for lithium-ion systems was commissioned on the grounds of Fraunhofer ICT, the institute's facilities and equipment have been continuously expanded. The following equipment is currently available:

Test box 1: Abuse tests, specific measurement set-ups

- Hydraulic press with press frame
- Nail test unit
- Various heating blocks for thermal tests on Li-ion cells
- High-current contactors for short-circuit tests

Test box 2: Disaster resistant climate chamber with vacuum function

- Test chamber volume 1 m^2
- Inertization with nitrogen is possible
- Sensor monitoring of the test chamber (O_2, CO, KWs)
- Vacuum up to 100 mbar
- Temperature cycles between -40 °C / +80 °C in 30 min.

Test box 3: Shock and vibration test

- Shaker unit with sliding table for specimens with a maximum load of up to 300 kg
- Drop-shock tester for test loads up to 85 kg

Battery cyclizers

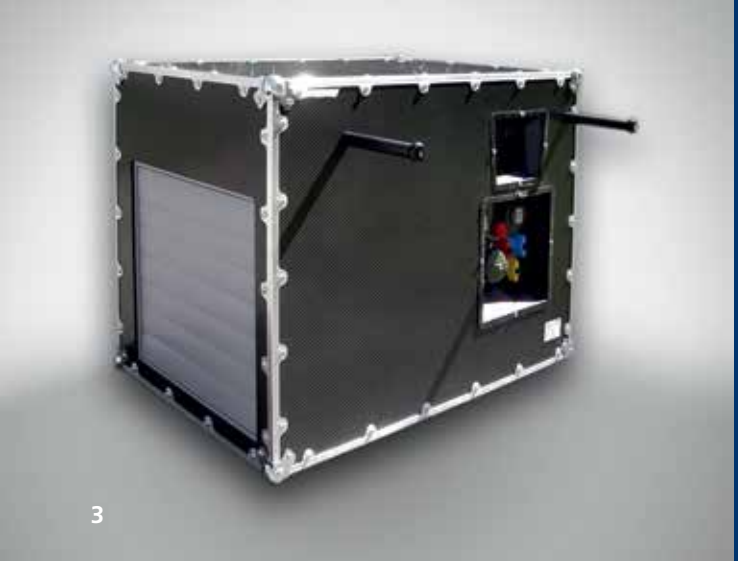
- Various cell testers
- Module tester
- Pack tester

Analytical equipment

- Online Fourier transform infrared spectrometer (FTIR)
- Online capillary mass spectrometer (MS)
- Adline gas chromatograph (GC)
- Gas chromatograph with mass spectrometer (GC-MS)
- Ion chromatograph (IC) and capillary electrophoresis (CE)
- Optical emission by inductively coupled plasma (ICP-OES) etc.

REDOX-FLOW BATTERY

Redox-flow batteries enable optimized use of renewable energies from fluctuating energy sources such as wind or solar power plants. In general, however, this type of battery can also be used as a high-availability energy storage device in the network as well as an uninterrupted power supply. Redox-flow batteries are based on the principle of storing chemical energy in the form of dissolved redox pairs in external tanks. The current conversion takes place in a separate power module. Redox-flow batteries offer the possibility to scale energy and performance independently of each other. Due to their modular setup and comparatively simple construction, a long service life can be achieved with simultaneously high availability. Since the storage capacity is essentially determined by the amount of electrolyte solution, and the efficiency is more than 75 percent, this type of storage is interesting for large-scale applications. Redox-flow technology offers significant potential for innovation with a much longer lifetime than lead acid batteries.



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1 *Heated pressure vessel for (Li-ion) battery tests, and also to analyze and detect (gaseous) substances.*

2 *Vanadium redox-flow battery.*

3 *2 kW portable fuel cell power generator developed in cooperation with FutureE GmbH.*

Scientists at Fraunhofer ICT carry out research and development in the following areas:

- Investigation of new electrolytes, electrodes and membranes
- Optimization of energy and power density
- Reduction of material costs
- Development of prototypes for flexible testing and evaluation
- Stack development and system tests
- Modeling and simulation

FUEL CELLS

Research activities in the field of fuel cells include the development of materials with a focus on electrocatalysts, the development of innovative test methods with a focus on degradation analysis and system development for hybridized mobile applications (APU and range exenders), as well as special applications, for example in the military field. Electrochemical processes for possible industrial applications are also investigated.

Material development

Scientists at Fraunhofer ICT are researching new materials for different types of polymer electrolyte membrane cells:

- Catalysts with a low content of platinum metal, for cost-effective alkaline direct alcohol fuel cells
- Alcohol-resistant binder materials for alkaline direct alcohol fuel cells
- Alcohol-tolerant cathode catalysts for direct alcohol fuel cells
- Anode catalysts for HT-PEMFCs with increased tolerance to impurities in reformed fuels
- Supported anode catalysts for PEM electrolysis

The researchers use a number of special test methods developed at Fraunhofer ICT, such as a test cell to perform in-operando mass spectrometry tests under real HT-PEMFC conditions.

Degradation test

Increasing the service life of fuel cells in order to meet market requirements is an important challenge. A better understanding of degradation processes is an important prerequisite. Scientists at Fraunhofer ICT therefore work on innovative test methods to monitor degradation processes on the catalyst and individual cell level. Through the use of mass spectrometry as a fast analysis method, it is also possible to track events that occur only transiently. In addition to a series of cells for differential mass spectrometry on catalyst samples under LT and HT-PEMFC conditions, Fraunhofer ICT has a test stand for the online tracking of degradation indicators on individual cells under vehicle test conditions according to the test protocols proposed by the Japan Automotive Research Institute (JARI).

System development

Scientists at Fraunhofer ICT work on the development of systems adapted to specific applications.

- Weight reduction for portable direct alcohol fuel cells
- Space-optimized installation of fuel cell range extenders into existing systems
- Air-independent operation of fuel cells
- Protection of fuel cells against frequent air-to-air starts

At Fraunhofer ICT comprehensive infrastructure is available for environmental simulation.

Industrial electrochemistry

The expected availability of increasing amounts of surplus electricity from renewable sources means that new application possibilities must be investigated. The electrochemical, decentralized production of chemicals is an option. As a result of the possible decentralization, other important environmental advantages arise: for example, it is possible to save the energy required for concentrating the chemicals for transport, and to avoid the transport of hazardous goods. Based on their expertise in fuel cell electrocatalysis, scientists at Fraunhofer ICT are currently developing a process for the decentralized electrochemical production of hydrogen peroxide, with possible applications in pulp bleaching or in oxidation processes in fine chemical production.

SENSOR TECHNOLOGY

Electrochemical sensors can be used to detect many different substances in liquids or in the gas phase. They are currently widely used, for example in the fields of safety and security, environmental diagnostics, process control and medical technology. Compared to other types of sensors, electrochemical sensors are known for their high sensitivity, easy handling and low production costs. In particular the sensitive determination of low concentrations of substances presents a significant challenge for chemical sensors.

In addition to the classical use of electrochemical sensors, in which individual substances are specifically identified through the detection of characteristic features such as oxidation and reduction reactions, non-specific electrochemical investigations can be carried out on complex matrices. The measuring system can ‘learn’ to use various features for evaluation (fingerprinting). Cyclic-voltammetry-based pattern recognition is a simple and fast analysis tool for a wide range of applications.

Current areas of research and development at Fraunhofer ICT include:

- Development of high-sensitivity sensors for explosives detection in air or seawater
- Optimization and design of sensors for industry
- Development of sensor concepts for gases, liquids and solids, in particular for the detection of trace elements in the range from ppm to ppt
- Analysis of food and substance mixtures by electrochemical pattern recognition
- Development of an electrochemical sensor for traces of oxygen at elevated temperatures

4 *MEA electrode coating by manual hot spraying.*

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ANALYTICS

In the field of analytics the focus is on electrochemical problems, and comprehensive electrochemical and analytical equipment is available. The work often requires a combination with classical analytical methods. In the case of abuse tests of lithium-ion accumulators, gaseous and partially toxic components can be formed, which are often difficult and complex to detect. Through the use of chromatographic methods, components up to the ppm range can be qualified and quantified. Further activities cover the evaluation of new materials for electrochemical storage devices and converters. Methods such as thermogravimetric analysis (TGA) or differential scanning calorimetry (DSC) are used.

Other key research and development topics at Fraunhofer ICT include:

- Examination of undesirable corrosion effects and damage analysis in batteries and electronic components of any kind
- Measurement of volatile compounds
- Tightness measurements on batteries under vacuum
- Examination of components for leaks, using helium
- Hydrogen monitoring of fuel cells using online mass spectrometry
- Determination of the permeabilities of membranes
- Differential electrochemical mass spectrometry for the elucidation of electrochemical reaction mechanisms
- Analysis of surface phenomena
- Development of capillaries for capillary electrophoresis
- Development of analytical procedures, together with electrochemical detectors and detection techniques, and their evaluation

OUR OFFER

With our many years of expertise and our various competences in the fields of applied electrochemistry, we are happy to assist you with your civilian and defense-related questions.

We carry out studies tailored to your needs, promote the transfer of knowledge through our experts and develop customer-specific solutions. Our contact persons will be happy to advise you.

5 *Test system for calibration gas generation for sensor characterization.*
6 *Flow through the FFE cell.*

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